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STUDY AND BEHAVIOUR OF REINFORCED CONCRETE SPECIMENS UNDER VARIOUS ELEVATED TEMPERATURES

R.A. Priyadarshan, N. Parthasarathi, K.S. Satyanarayanan and V. Thamilarasu
Department of Civil Engineering, SRM University,
Kattankulathur, Tamilnadu, India

ABSTRACT

Concrete is a composite material composed of coarse aggregate, fine aggregate bonded together with fluid cement which hardens over time resulting in RC structures. However all the structures are prone to damage when exposed to relatively high temperatures to that of the atmospheric temperature. Current scenarios show us that due to the development in technology, human carelessness has increased. Being completely reliant on technology even for safety purposes may lead to undesirable accidents, one of which is fire accidents in buildings. Reinforced concrete may be a very hard and durable material, but it has its own threshold points. After which the concrete disintegrates with the rise in temperature. As the temperature increases to a considerable extent, say 500℃, concrete eventually starts losing its integrity and stiffness. In this project RC short columns are to be studied in specific because columns are the most important and critical members of any structure. That too, in most of the cases, we ought to use only short columns in our construction. Hence studying their behaviour when exposed to various elevated temperatures may help us in knowing about its effects and also helps us in improving the design strategies against fire outbreaks in RC structures. Here, conventional concrete specimen like 15 cubes and 15 cylinders of grade M30 were casted and heated to various elevated temperatures like 500℃,600℃,700℃,800℃in the heating oven and then tested. The test results gave us the compressive strength, split tensile strength and Young's modulus values which will be very helpful in developing the heat resistant design strategies.

Key words: elevated temperature, compression strength, split tensile strength, Young's modulus.

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1. INTRODUCTION

Concrete is a composite material made up of fine aggregates, coarse aggregates, cement and water. It is highly durable and resistant against compressive stresses occuring in buildings and also resistant against fire to a much larger extent than other materials. However concrete also has its cons. When subjected to large temperatures it tends to damage and disintegrate. Hence concrete structures must still be designed for fire effects. Structural components still must be able to withstand dead and live loads without collapse even though the rise in temperature causes a decrease in the strength and modulus of elasticity for concrete and steel reinforcement. In addition, fully developed fires cause expansion of structural components and the resulting stresses and strains must be resisted.

The behaviour of concrete in fire depends on its mix proportions, constituents and the cover provided. It is determined by complex physiochemical transformations during heating. Any structural analysis of heated concrete that ignores transient creep will yield erroneous results, particularly for columns exposed to fire. Failure of structural concrete in fire varies according to the nature of the fire; the loading system and the type of the structure. Failure could occur from loss of bending or tensile strength; shear or torsional strength; loss of compressive strength; and spalling of concrete. The structural element should should, therefore, be designed to fulfill its separating and load bearing function without failure for the required period of time in a given fire scenario.

Design for fire resistance aims to ensure overall dimensions of the section of an element sufficient to keep the temperature of the reinforcement below critical values long enough for the required fire resistance period to be attained. In recent years, researchers have focused on the improvement of fire resistant design in Reinforced concrete structures by using NDT testing methods and so on. Hence it gets to be as an important aspect to be studied.

During hydration reaction calcium hydroxide $Ca(OH)_2$ and calcium silicate hydroxide are produced as shown in the following equation:

$$2CaSiO_5 + 7H_2O \rightarrow 3CaO.2SiO_2.4H_2O+3Ca\ (OH)_2+173.6kJ$$

One of the advantages of concrete over other building materials (steel, wood,..) is its fire resistive properties. It is regarded as a fireproof because of its incombustibility and its ability to withstand high temperatures without collapse. However, its properties can change dramatically when exposed to high temperatures and many problems were experienced with concrete in fire such as deterioration in mechanical properties

2. SUMMARY OF LITERATURE REVIEW

A review is presented based on experimental studies on the performance concrete when exposed to higher temperature. The compiled test data revealed distinct difference in mechanical properties of normal, high strength and self compacting concrete. Shape of specimen (cube, cylinder, beam etc), size of specimen, magnitude of temperature load applied on the specimen, time duration maintained for heating, reference on time-temperature curve, rate of heating, rate of cooling, time taken for hot test after curing period, time taken for load test after heating, heat test on stressed/unstressed member, type of cooling adopted on heated specimen by natural cooling or cooling by spraying water etc are the parameters that influence the test results.

3. MATERIALS AND METHODS

As only conventional concrete is involved in this project, cementitious material used was ordinary Portland cement (OPC).The coarse aggregates used are the continuous grading crushed gravel, with the maximum particle size of 20 mm. The fine aggregates are river sands, with a fineness modulus of 2.8.

Ordinary Portland cement of grade 53 with properties confirming with IS 12269-2009 were used. The specific gravity and fineness modulus of cement were 3.14 and 6 respectively.

The locally available river sand was used as fine aggregate in the present study. The fine aggregate was tested for various properties such as specific gravity, fineness modulus and sieve analysis and are conforming to standard specifications. The sand used confirms to grading zone II of IS 383:1970.

The specific gravity and fineness modulus of sand were 2.68 and 3.01 respectively. Sand is sieved through IS 2.36 mm Sieve and the same is used throughout the experiment.

Table 1 Properties of fine aggregate

S.No	Properties	Results
1	Bulk density kg/m3	1650
2	Specific gravity	2.68
3	Fineness modulus	3.01
4	Free surface moisture %	2.0

The crushed aggregate was used from the local quarry. In this experiment the aggregate was used of 20mm down and tested as per IS: 2386-1963(I, II, III) specification. The properties of coarse aggregate are shown in Table 2.

Table 2 Properties of Coarse aggregate

S. No	Properties	Results
1	Bulk density kg/m^3	1800
2	Specific gravity	2.74
3	Fineness modulus	4.6
4	Maximum nominal size	20mm

4. RESULTS AND DISCUSSION

4.1. Compressive Strength

The cube specimen was casted and cured for 28 days to attain their whole compressive strength. Then for each of the temperature 3 numbers of cube specimen were used.(i.e) 3 cubes for 500℃, 600℃, 700℃& 800℃respectively.The cubes were placed in the heating oven and their respective temperature was set accordingly. After the decided temperature has been attained the oven was turned off and the specimen was let to cool to take them to the testing machine. Another set of 3 cubes were tested conventionally without heating. Then finally the results of the conventional and heated specimen were compared using a bar graph chart. Given below are the results acquired in the compressive strength test.

Table 3 Compressive strength of M30 grade cube specimen

Type of specimen	Compressive strength at 28 days(kn/㎡)
CONVENTIONAL	36
500℃	20.5
600℃	17.6
700℃	15.2
800℃	13.45

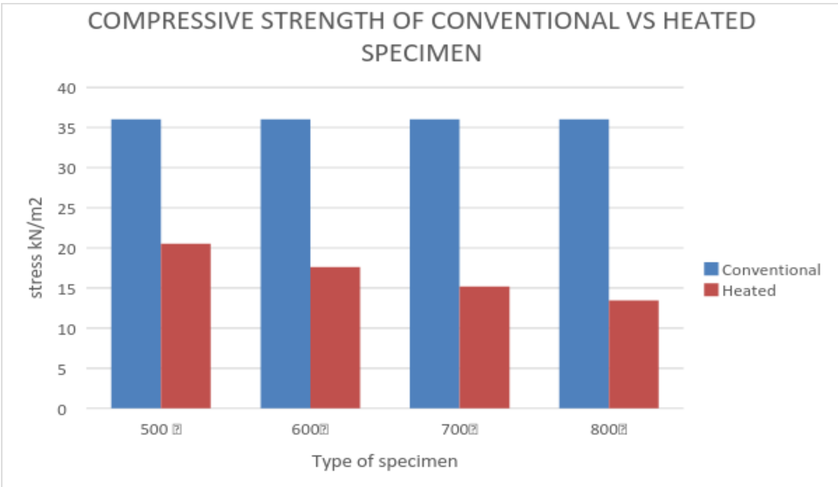

Figure 1 Variation in compressive strength of M30 grade conventional specimen vs heated specimen

4.2. Split-Tensile Strength

After casting and 28 days of curing the cylinder specimen, they were subjected to heating in the oven.3 numbers of specimen for each of the temperature from 500℃-800℃were used. The cylinders were placed in the heating oven and their respective temperature was set accordingly. After the decided temperature has been attained the oven was turned off and the specimen were let to cool and taken to the testing machine. Another set of 3 cubes were tested conventionally without heating. Then finally the results of the conventional and heated specimen were compared using a bar graph chart .Given below are the results acquired in the split-tensile strength test.

Table 4 Split tensile strength of M30 grade cylinder specimen

Type of specimen	Split tensile strength at 28 days(kn/㎡)
CONVENTIONAL	2
500℃	1.09
600℃	0.97
700℃	0.90
800℃	0.86

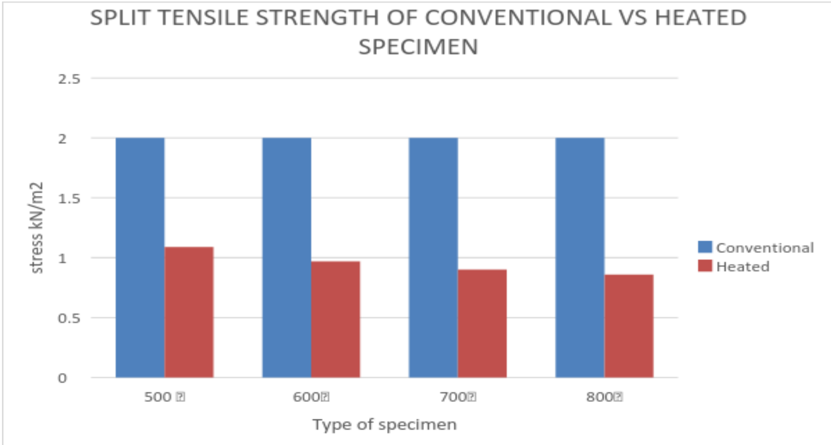

Figure 2 Variation in split tensile strength of conventional M30 grade specimen vs heated specimen

4.3. Modulus of Elasticity

Cylinders were also casted for the testing of the Young's modulus or Modulus of elasticity values of the heated specimen.3 numbers of specimen were used for each temperature to arrive at a mean value.3 nos of specimen were heated to 500℃,600℃,700℃ and 800℃respectively and 3 nos of specimen were tested for Young's modulus values without heating so as to compare their results. Shown below are the stress-strain curves obtained for each type of specimen.

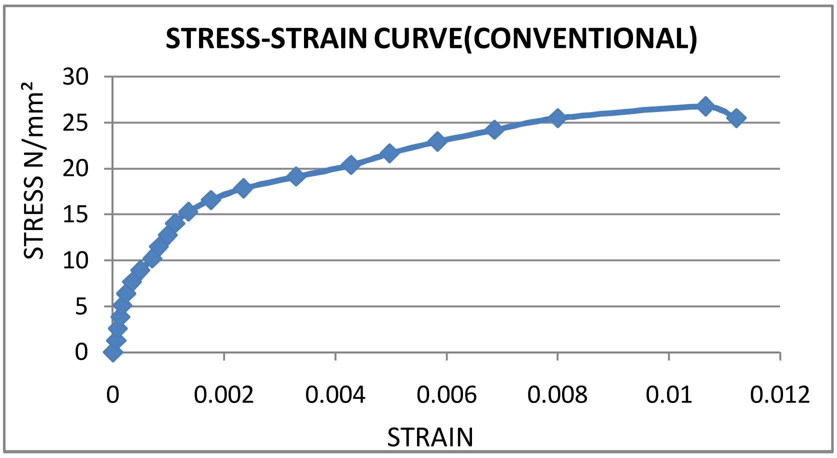

Figure 3 Stress-strain curve for conventional M30 grade specimen

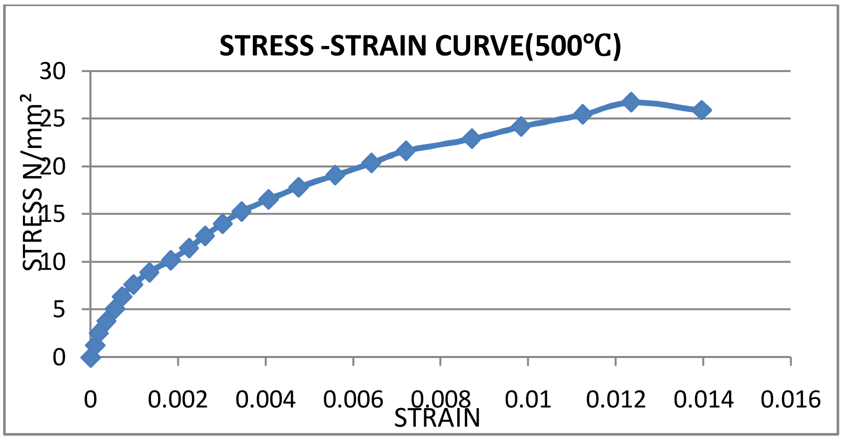

Figure 4 Stress-strain curve for 500℃heated M30 grade specimen

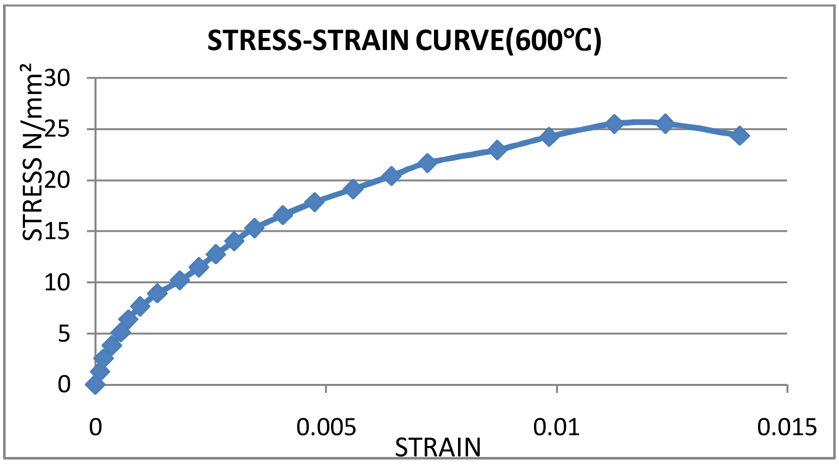

Figure 5 Stress-strain curve for 600℃heated M30 grade specimen

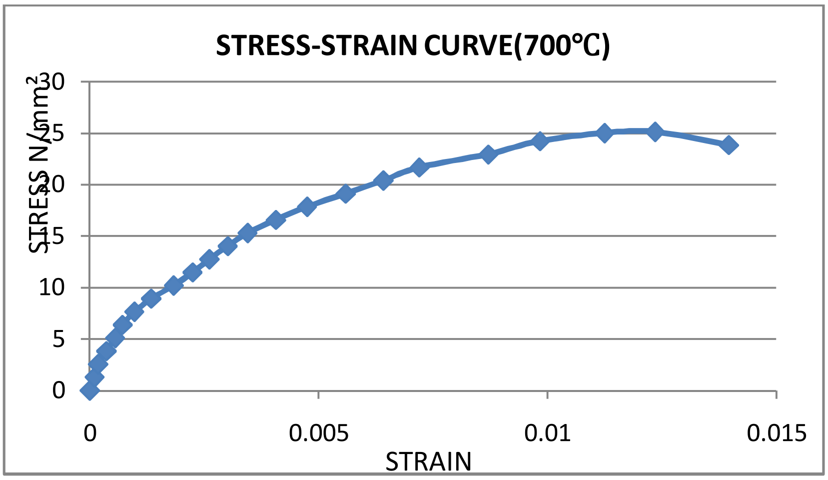

Figure 6 Stress-strain curve for 700℃heated M30 grade specimen

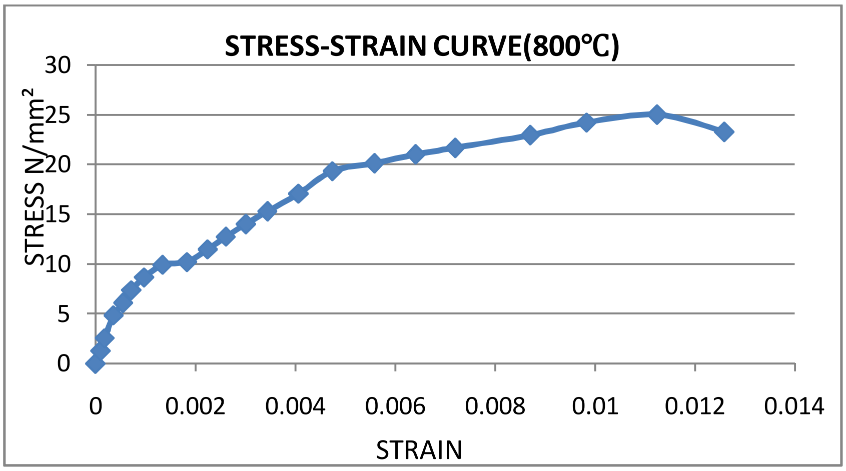

Figure 7 Stress-strain curve for 800℃heated M30 grade specimen

The compressive strength of conventional concrete of M30 grade is obtained to be 36 KN/㎡ at 28 days. Whereas the heated specimen of the same M30 grade show a drastic decrease in its strength properties. The cube specimen which was heated upto 500℃ showed a drastic 43% decrease in its compressive strength. The specimen which was heated to 600℃ showed a decrease of 52% in the compressive strength.700℃ and 800℃ heated specimen

showed a loss of 58% and 62% respectively. It is because when the concrete is heated above 500℃ it loses its integrity and also all the hydration water. The calcium hydroxide in the specimen starts to decompose thus producing a large reduction in density. Same is the case in split tensile strength of the specimen too. The conventional M30 grade specimen had a split tensile strength of 2KN/㎡.Whereas the heated specimen showed a reduction in split tensile strength such as 1.09KN/㎡,0.97KN/㎡,0.9KN/㎡,0.86KN/㎡for 500℃, 600℃, 700℃& 800℃ heated specimen respectively. This is because as the temperature increases the rigidity and stiffness of the concrete tends to get reduced and hence they show a greater elongation properties thus resulting in lesser split tensile strength. The Young's modulus values or the stress-strain curve values also show a considerable increase. These values increase because due to an increase in temperature the concrete tends to disintegrate and elongates more. Thus these are the results obtained in the testing of M30 grade concrete specimen after subjected to heating.

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